In-situ synchrotron studies of metal-organic chemical vapor deposition of $In_xGa_{1-x}N$

Scientific Achievement

Light emitting layers in nitride LEDs and lasers consist of $In_xGa_{1-x}N$, typically grown by metal-organic chemical vapor deposition (MOCVD). Inability to produce sufficiently high quality material with high indium content is impeding progress in development of high-efficiency solid-state lighting. Using our unique facility at the Advanced Photon Source for real time x-ray scattering and fluorescence studies of MOCVD growth, we have carried out the first *in situ* measurements of atomic scale structure and composition during MOCVD of $In_xGa_{1-x}N$. We observed the indium coverage of the GaN surface under growth conditions with sub-monolayer sensitivity using synchrotron x-ray scattering and fluorescence techniques. By monitoring the changes in coverage in real time as a function of temperature and indium precursor (TMI) flow, we could determine the condensation phase boundary. Through a combination of x-ray fluorescence and reflectivity, we determined the equilibrium indium surface coverage below the condensation boundary. As TMI pressure is increased, the fluorescence shows an initial rapid increase in coverage, which is not shown in reflectivity. Since reflectivity is more sensitive to adatoms on the surface terraces than to those on the step edges, while fluorescence is equally sensitive, this indicates significant preferential indium attachment at step edges. These studies are the first steps towards experimental determination of indium incorporation mechanisms.

Significance

Understanding the incorporation of indium during synthesis of $In_xGa_{1-x}N$ materials by MOCVD is a fundamental materials problem that is key to continued improvement in the performance of light-emitting diodes for energy efficient lighting. We are developing synchrotron radiation techniques into powerful tools for *in situ* studies of materials processing in reactive environments such as MOCVD. Real time x-ray studies during MOCVD growth of $In_xGa_{1-x}N$ provide the first direct views of the atomic-scale processes as they occur. We anticipate that these will give important experimental insights into indium incorporation mechanisms, which will allow optimized synthesis procedures to be designed. In addition, we will be able to determine whether indium-rich nano-regions, thought to be a significant factor in light emission efficiency, are present in as-grown quantum wells. Through this collaboration with industrial researchers, our fundamental materials synthesis studies will be targeted at questions with direct practical impact.

Performers

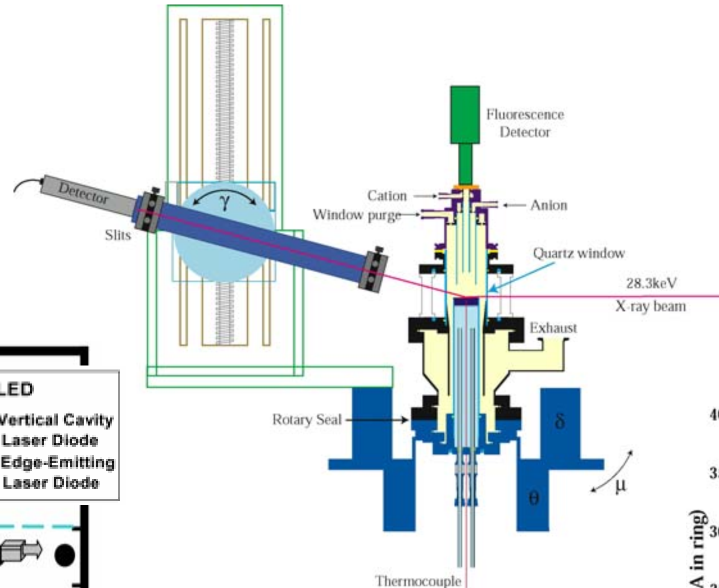
F. Jiang, S.K.Streiffer, R.-V. Wang, P.H. Fuoss, G.B. Stephenson (ANL-MSD)

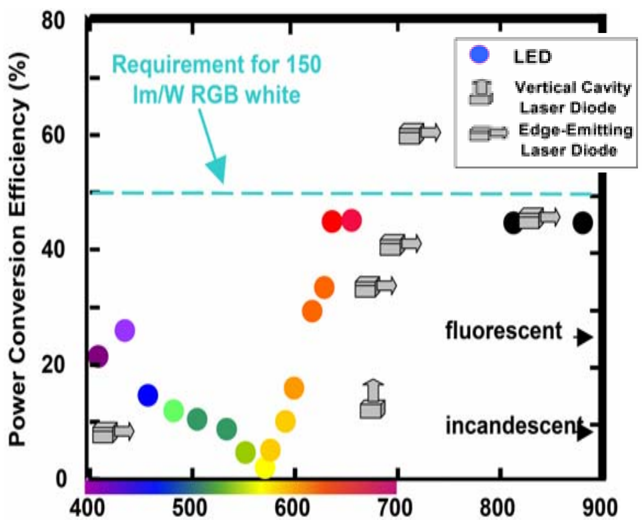
A. Munkholm (Lumileds Lighting)

C. Thompson (Northern Illinois Univ.)

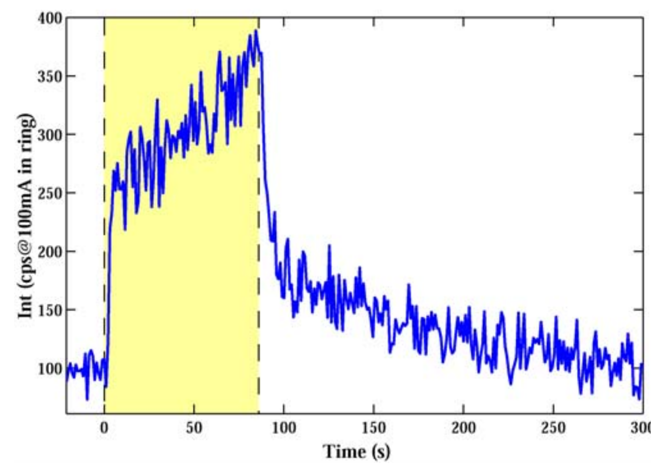
In Situ Synchrotron X-ray Studies of Metal-Organic Chemical Vapor Deposition of $In_xGa_{1-x}N$

Indium incorporation is critical to LED performance for solid-state lighting





Real-time X-ray fluorescence during indium dosing at 756 C



Using X-ray scattering and fluorescence, we can understand the atomic scale mechanisms of indium incorporation in $In_xGa_{1-x}N$ during film growth by MOCVD

Fan Jiang, S.K. Streiffer, R.-V. Wang, P.H. Fuoss, G.B. Stephenson (ANL-MSD)

Materials Science Division
ARGONNE
NATIONAL LABORATORY

A. Munkholm (Lumileds Lighting), C. Thompson (Northern Illinois Univ.)